

House fly ecological differences may be significant - i.e. poultry houses^{vs} dairy^{vs} swine etc



Teamwork

(8% of Total resources @ IAMA)

- Programmer
- Computer specialists (Modeling specialists)
- Ecologist

David H. - "You can work on a model almost forever"

- When is it finished?

- when it is validated

- not necessarily exact but could be as an index - i.e. #/trap or #/sampling unit

What do you do about parasite/predator factor?

UN 9 1987
I have checked this proof.
I have marked all changes or
corrections I wish to be made.

Signed _____

Telephone _____

Computer Simulation of Area-wide Management Strategies for the Lone Star Tick, *Amblyomma americanum* (Acari: Ixodidae)

G. A. MOUNT¹ AND D. G. HAILE

Insects Affecting Man and Animals Research Laboratory,
Agricultural Research Service, U.S. Department of Agriculture,
Gainesville, Florida 32604

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ABSTRACT A computer model was developed to simulate effects of management technologies on populations of lone star tick, *Amblyomma americanum* (L.), in areas where White-tailed Deer, *Odocoileus virginianus* (Zimmerman), are the principal host. Technologies considered in this study were acaricide application for area-wide management of unfed ticks, vegetative management to remove leaf litter and duff that provide a suitable microenvironment for free-living ticks, and host management to reduce density of deer. Computer simulations were made with normal weather patterns and other variables for eastern Oklahoma. Simulations with each technology alone suggested that either six acaricide applications, vegetative management against 100% of the tick population in a 4-yr cycle, or host management to attain a density of 2.47 deer per 100 ha for all years would be necessary to reduce densities of the lone star tick below an arbitrary threshold level during a period of 10 yr. Simulations with technologies at lower levels than indicated above were used to develop integrated management strategies that could be considered for practical use against populations of the lone star tick.

KEY WORDS *Amblyomma americanum*, *Odocoileus virginianus*, computer simulation, management strategies

THE LONE STAR tick (LST), *Amblyomma americanum* (L.), is an important pest and vector species affecting humans in recreational areas of the southeastern and south-central United States. LST is particularly abundant in large recreational areas that support high densities of White-tailed Deer (WTD), *Odocoileus virginianus* (Zimmerman), such as Sequoyah State Park in northeastern Oklahoma (Haile & Mount 1987) and Land Between the Lakes in western Kentucky and Tennessee (Cooney & Burgdorfer 1974). Past and current efforts to manage LST in recreational areas consist of applications of acaricides and vegetative management in high-use areas only. This approach to management provides seasonal reductions in localized densities of LST but no measurable reduction in overall populations. Thus, present management programs provide no protection for human visitors from LST attack while hiking, hunting, or engaging in any activity away from a protected high-use area. A broader approach to management than is currently practiced will require more extensive knowledge of the potential effects of management technologies and strategies on long-term population levels.

Long-term field studies with various technologies against LST will be costly because of the time required to obtain meaningful results and the need

for large or isolated study areas to eliminate the effects of host movement. Therefore, we think that modeling and computer simulation methods will enhance the development of efficient management strategies against populations of LST. Simulation studies will not eliminate the need for field trials but should provide guidance in selection of methods for testing and experimental design.

In a previous paper (Haile & Mount 1987) we presented a computer simulation model of LST (LSTSIM) based on the tick's life history. This model was designed to assist other research efforts in the study of population dynamics and in the development of long-term management strategies for LST. The previous paper dealt with construction and validation of the model and presented simulation results on various aspects of growth rate, generation time, and seasonal activity of LST as affected by weather, habitat, host density, and geographic location. The present paper extends the previous work to include simulation of management strategies.

Our objectives were to develop and validate submodels of management technologies for incorporation into LSTSIM and to simulate the effectiveness of technologies alone and in various combinations for long-term management of LST populations. This paper describes the development and validation of the submodels based on available data and the computer simulation methodologies

¹ Formerly, Lone Star Tick Research Lab., ARS-USDA, Poteau, OK 74953 (1977-84).

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RH: MOUNT & HAILE: LONE STAR TICK MANAGEMENT STRATEGIES

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PP. 278-310

Table 1. Factors for basic efficacy (F_1)^a during each week following an area-wide AA against unfed life stages of LST

	Wk posttreatment			
	1	2	3	4
Larvae	0.98	0.83	0.45	0.12
Nymphs	1.00	0.68	0.34	0
Adults	0.53	0.35	0.18	0

^a F_1 represents reduction in density when factors for age susceptibility (F_2 , Table 2) and host finding (F_3) = 1.

used to study the effectiveness of management technologies. We also discuss integrated strategies for management of LST.

Construction of Management Submodels

The management technologies considered in this study for use against populations of LST in areas where WTD is the principal host include area-wide application of acaricides (AA), vegetative management (VM), and host management (HM). Our approach was to develop submodels, based on available data, to quantitate the dynamic effects of management on the growth of LST populations. For consistency, the management submodels used the same weekly time steps and age classes as LSTSIM. Precise data on relationships between environmental variables and management efficacy were generally lacking. Thus, of necessity, some factors and relationships were approximated to develop the submodels. In some cases values were refined from the submodels by comparisons of simulated effectiveness with actual data.

Acaricide Application (AA). The most practical method of AA for area-wide management of LST over large, unimproved areas is aerial application of granular formulations as discussed by Mount (1984a). Successful management of LST can be achieved with aerial application of liquid formulations (Mount et al. 1968), but the liquid method requires higher doses (2-fold labeled rates or more) because of the apparent loss of acaricide in the overstory above LST habitat. The effectiveness of organophosphorus (OP) acaricides for area-wide management of LST was first documented by Mount et al. (1968) and many additional studies in Kentucky, North Carolina, and Oklahoma have been reported (Clymer et al. 1970, Hair & Howell 1970, Mount et al. 1970, 1971, 1976, Hoch et al. 1971, Cooney & Pickard 1972, Darrow & Whetstone 1972, Grothaus et al. 1975, Roberts et al. 1980, 1984, Barnard et al. 1981, Mount 1981a,b, 1983, 1984a,b, Mount & Whitney 1984). Based on these laboratory and field assays, chlorpyrifos and tetrachlorvinphos have EPA registrations for area-wide tick control. A third OP acaricide, diazinon, has been registered (24C) for use against free-living LST in one state (Oklahoma).

Table 2. Factors for relative susceptibility to AA for different age groups within each unfed life stage of LST

	Age (wk postmolt)	Susceptibility factor
Larvae	2-3	1.0
	>3	2.0
Nymphs	2-9	0.5
	10-40	1.0
	>40	2.0
Adults	3-20	0.2
	21-40	1.0
	>40	2.0

Because the effectiveness of these OP's is similar when applied at labeled rates, the AA submodel was constructed using mean data for all three to simulate the effect of any one acaricide. The AA submodel was designed to determine the reduction in density of each age class of unfed LST during each week posttreatment from the product of three factors as follows: percent reduction = $F_1 \times F_2 \times F_3 \times 100$, where F_1 = basic efficacy factor for a single treatment during each posttreatment week (Table 1), F_2 = relative susceptibility factor for different age groups within each host-finding stage (Table 2), and F_3 = factor for host-finding activity representing the effect of varying temperature and daylength (calculated in LSTSIM and varies between 0 and 1).

The values of F_1 for OP acaricides in Table 1 were derived from studies by Mount et al. (1976) and Mount (1981a,b, 1983) and represent the weekly reductions for the largest cohort of each unfed life stage during optimum conditions of host finding (F_2 and F_3 = 1). Values for F_2 in Table 2 were based on data reported by Mount et al. (1970), Darrow & Whetstone (1972), and Mount (1984b), which showed an increase in susceptibility to OP acaricides with increasing age within each life stage of unfed LST. The host-finding factor (F_3) from LSTSIM was included in the model as a means of simulating the positive relationship between acaricidal effectiveness and host-finding activity suggested by data in Mount (1984b). The program limits percent reduction to 100 because the calculated percent reduction for the oldest age group within each stage (F_2 = 2) can be >100 when F_3 is near 1. This does not suggest that the AA model is unrealistic, because the labeled rates of OP acaricides will provide >LD₁₀₀ against the oldest age groups within each unfed stage, especially larvae. Although factors for the effect of AA were derived from available data, some adjustments were made to factors for basic efficacy and age/susceptibility so that simulation results were similar to actual results reported by Mount (1984b).

Vegetative Management (VM). In small-plot tests, Hair & Howell (1970), Clymer et al. (1970), and Hoch et al. (1971) reported that mechanical clearing to remove ca. 75% of overstory and all understory vegetation provided 24-47% reduction,

Table 3. Rates of host finding by LST at optimum temperature and daylength used in a model of host management based on reduction in the density of WTD

Hosts ^a		Deer density (no./100 ha)				
		24.70	12.35	6.18	2.47	0
Larvae	WTD	0.017	0.012	0.008	0.004	0
	All	0.042	0.037	0.033	0.029	0.025
Nymphs	WTD	0.028	0.020	0.014	0.007	0
	All	0.070	0.062	0.056	0.049	0.042
Adults	WTD	0.035	0.025	0.017	0.009	0
	All	0.036	0.026	0.018	0.010	0.001

^a The rate of host finding for hosts other than WTD was held constant at a value of 60% of 0.042 for larvae, 60% of 0.070 for nymphs, and 3% of 0.036 for adults.

53–72% reduction, and 39–85% reduction of LST in Oklahoma during the 1st, 2nd, and 3rd yr post-treatment, respectively. A large-scale study by Mount (1981c) indicated that ongoing VM programs, which consisted of partial removal of over-story, removal of all understory, and frequent mowing to maintain the height of grasses at <15 cm, reduced populations of LST by 85% compared with adjacent unmanaged areas. The controlled burning of leaf litter and duff as another VM tool was studied on small plots in Oklahoma by Hoch et al. (1972). Those investigators reported 35–67% net mortality of marked/released LST during summer burns; however, substantial numbers of indigenous LST were also recovered in burned plots. Furthermore, the senior author studied the effects of controlled winter burns on the seasonal densities of populations of LST in plots (24 by 24 m) during 1982 and 1983 in typical oak–hickory habitat in Oklahoma (G.A.M., unpublished data). Seasonal densities of larvae (sampled by drag method) and of nymphs and adults (sampled by dry-ice method) were reduced by 56, 52, and 59%, respectively, in controlled-burn plots compared with untreated plots. Overall, these cited studies on controlled burning indicated that this technology has the potential to reduce densities of LST by direct contact with fire and, more important, to reduce the survival rates of free-living life stages by the elimination of a protective mulch consisting of dried vegetation, leaves, and duff.

Our VM submodel was based only on the reduction in the survival rates of the free-living life stages of LST. Reductions in weekly survival rates for unfed larvae (6%), nymphs (4%), and adults (4%) were calculated from seasonal differences in densities of LST on vegetatively managed and unmanaged plots (G.A.M., unpublished data). Reductions for eggs (6%), engorged larvae (15%), engorged nymphs (12.5%), and engorged adult females (5%) were extrapolated from studies previously cited on VM versus LST and from a comprehensive study on the survival of free-living life stages of LST in three types of habitat over a 3-yr period (Koch 1984). However, several adjustments in the percent reductions in survival rates were

based on comparisons of preliminary simulation results with the results of controlled-burn studies (G.A.M., unpublished data).

Host Management (HM). Studies in Oklahoma (Bolte et al. 1970, Clymer et al. 1970, Patrick & Hair 1977, 1978) and in Kentucky and Tennessee (Cooney & Burgdorfer 1974) indicated that the principal wildlife host of adult LST was WTD. Furthermore, those studies showed that WTD also serve as an important host of immature LST. Possible reasons for the overall suitability of WTD as a host for LST are the physiological suitability of this host for the feeding of LST; the wide-ranging movements of the host that facilitate host finding by LST, which has a clumped distribution; and the browsing habits of the host in wooded habitat where the free-living stages of LST have the highest rates of survival (Koch 1984). A WTD exclusion study by Bloemer et al. (1986) indicated that seasonal reductions in densities of LST on a WTD-excluded plot versus densities on an adjacent untreated plot were 98, 38, and 22% for larvae, nymphs, and adults, respectively, of LST. These reductions provided evidence of the proportion of each preceding life stage that fed on WTD. However, as indicated by Bloemer et al. (1986), seasonal densities of LST also reflected a difference in host-finding rates on plots where WTD were either absent or present. Thus, a further analysis of data provided by Bloemer et al. (1986), limited to the first three sampling intervals for each life stage, suggested that 95–99% of adult LST and 35–45% of immature LST had fed on WTD. Furthermore, this analysis suggested a relationship between the density of WTD and the proportion of LST that fed on this host.

The HM submodel (Table 3) was based on the proportion of each life stage of LST that feeds on WTD in a wildlife ecosystem and on a relationship between host density and host-finding rate. For the HM submodel we chose to use the mean proportions for feeding on WTD (97% for adults and 40% for immatures) suggested by Bloemer et al. (1986) for high densities of hosts as defined in LSTSIM by Haile & Mount (1987). Sutherst et al. (1977) indicated that decreases in rates of host finding of a one-host tick were not equivalent to decreases in host density. We extrapolated from their work to include the effect of host density in LSTSIM and in our HM submodel by decreasing rates of host finding by 30% for each 50% reduction in the density of WTD. We assumed that the rates of host finding for the alternate hosts of LST remained constant. For 100% reduction in the density of WTD we also assumed that the rates of host finding were equal only to the rates for the alternate hosts of LST. Table 3 shows the rates of host finding for LST at optimum temperature and daylength for the different densities of WTD used in the HM submodel. The HM submodel was designed to adjust host densities with each change in the density of WTD, while densities of alternate hosts remained constant.

Table 4. Comparison of actual and simulated area-wide management of LST in eastern Oklahoma (AA is followed by the week of treatment; VM100 is vegetative management against 100% of the free-living tick population)

Management technology	% reduction					
	Actual $\pm$ SD			Simulated		
	Larvae	Nymphs	Adults	Larvae	Nymphs	Adults
AA17 ^a		86 $\pm$ 16	61 $\pm$ 19		84	71
AA18 ^b		94 $\pm$ 6	60 $\pm$ 20		89	75
AA19 ^b		83 $\pm$ 9	70 $\pm$ 14		92	81
AA20 ^a		97 $\pm$ 6	88 $\pm$ 12		95	83
AA19 + VM100 ^b		86 $\pm$ 12	88 $\pm$ 6		96	93
AA20 + VM100 ^c		99.9 $\pm$ 0.3	98 $\pm$ 4		98	93
AA30 ^a	94 $\pm$ 8			83		
AA33 ^c	85 $\pm$ 23			88		

^a Actual data from Mount (1984a).

^b Actual data from Mount & Whitney (1984).

^c Actual data from G.A.M. (unpublished).

Programming. The submodels for AA, VM, and HM were combined with LSTSIM, which was programmed in Advanced BASIC (BASICA) and compiled for execution on an IBM-PC (International Business Machines personal computer). The program will run on any IBM-PC-compatible microcomputer with a 360kb disk drive, graphics monitor, graphics printer, and 256kb random access memory. A color monitor is desirable because the program makes use of color statements for most screen displays and graphics. A hard disk system is helpful for storing input and output data files.

LSTSIM includes a management option that allows selection of any one of the management technologies alone or in any possible combination. Additional menu options offer various levels of each management technology. AA offers a choice of the total number of treatments and the timing (week number) for each application. AA is programmed for coverage of 100% of the target population of host-seeking LST. VM offers options of 25, 50, or 100% coverage of the target population of free-living LST each year. HM offers options of 50, 75, 90, or 100% reduction in the density of WTD each year. The options for VM and HM are implemented during week 1 of each year of simulation and cannot be changed within years. Long-term simulations with management technologies are accomplished with either yearly input from menu options or with input from data files constructed specifically for various management strategies.

LSTSIM provides a graphical plot on the computer display of the weekly population of ticks on hosts during each year of simulation. When AA is selected, the plot includes arrows and audio signals for each week of application (numbered 1-52 through calendar year). Documentation of the effects of management technologies is accomplished by printouts of densities of all life stages for all weeks of a simulation year and with text summaries of numbers of unfed larvae, nymphs, and adults per hectare during peak periods for each stage (April through June for nymphs and adults, August for larvae).

The AA, VM, and HM submodels were programmed without regard to the clumped distribution of LST or possible reinfestation by movement of infested hosts from unmanaged areas into a managed ecosystem.

Validation

Our approach to validation of the management submodels involved comparison of simulated management results with data from field studies not used in the construction of the submodels. Initial LST populations for AA and VM simulations were generated by simulating population growth for 15 yr under "normal" weather conditions and then 7-9 additional yr under annual weather conditions starting with 1974 up to the year with field data for comparison (1981-83). The "normal" weather conditions were based on an average of 3 yr of weather data collected by Koch (1984) in eastern Oklahoma; the annual weather conditions were based on data for eastern Oklahoma supplied by the National Climatic Data Center, Asheville, N.C. The effectiveness of AA and AA + VM simulations was determined by comparisons with unmanaged simulations. Table 4 provides extensive validation of the AA submodel for all unfed life stages of LST and limited validation of the VM submodel when used in combination with the AA submodel against nymphs and adults. Table 4 also shows that 16 of 18 simulation results are ± 1 SD of actual results. Moreover, these comparisons show that the AA submodel provides realistic results when used at various times during the season of activity and against the different life stages of LST.

Partial validation of the HM submodel is provided by simulation of HM100 (100% reduction of WTD) with historical weather data from Nashville, Tenn. This simulation was initiated with a file generated by 15 yr of growth of LST with the same weather data. The simulation results indicated a 95% reduction in larvae of LST during the 1st yr of simulation, with little change in densities of nymphs and adults. For comparison, unpublished

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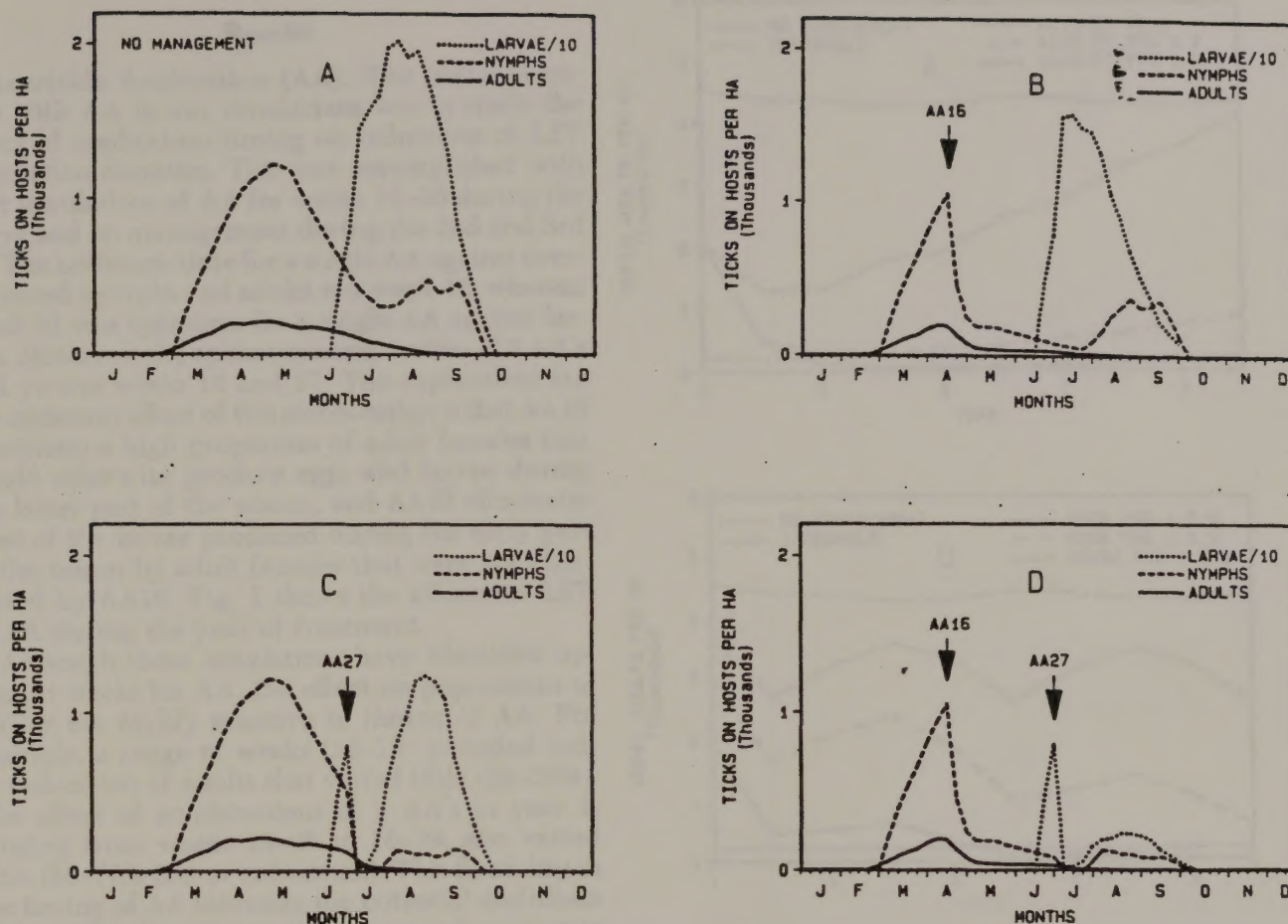


Fig. 1. Simulated effects of (A) no management, (B) AA16 alone, (C) AA27 alone, and (D) AA16 and 27 combination during optimum weeks of the year on seasonal densities of parasitic LST (on hosts) in eastern Oklahoma with a normal weather pattern.

data provided by R. H. Zimmerman (USDA/TVA pilot test on integrated tick management in recreational areas, Golden Pond, Ky.) showed a 98% reduction in larvae of LST and essentially no change in numbers of nymphs and adults in a WTD exclusion study in a 67-ha recreational area at the southern end of Land Between the Lakes, ca. 100 km northwest of Nashville.

Simulation of Management Strategies

Simulations were run to study the effects and characteristics of each management technology alone and in all possible combinations of technologies. Our goal was to determine the minimum level and frequency of each technology or combination of technologies needed to reduce and maintain population levels of LST below an arbitrary threshold suggested by Mount & Dunn (1983). This threshold was based on a relationship between numbers of LST sampled with a dry-ice method and those sampled with human subjects. The suggested threshold of 0.65 ticks (both adults and nymphs) per 1-h dry-ice sample is equal to 222 unfed adults per hectare (with a 1:5 ratio of unfed adults to nymphs).

Management of populations of LST in eastern Oklahoma was simulated with input variables as defined by Haile & Mount (1987). These variables consisted of normal weather; a habitat ratio of 0.2 bottomland wooded, 0.7 upland wooded, and 0.1 meadow; high host densities; 1.0-fold host-finding factor; and 36°N latitude daylength. For typical LST habitat in eastern Oklahoma, we estimated that 0.2, 0.7, and 0.1 of the tick population (all stages) would be found in bottomland, upland, and meadow habitat, respectively. These variables provide a maximum rate of growth per generation (R) of 2.02. Each simulation was initiated with an equilibrium population file produced by 15 yr of growth with the input variables. Three-year simulations were made to study the timing of AA versus population reduction. Ten-year simulations were run to determine the long-term effects of management technologies on the densities of LST. In this simulation study, we used densities of unfed adults as an index to compare managed and unmanaged population trends. The only difference between adults and immatures for comparing densities is that reductions in populations of immatures, especially larvae, would occur more rapidly because of their reduced longevity.

Results

Acaricide Application (AA). The initial objective with AA in our simulations was to study the effect of application timing on reductions of LST population densities. This was accomplished with 3-yr simulations of AA for weeks 13–35 during the 1st yr and no management during the 2nd and 3rd yr. The optimum time for a single AA against overwintered nymphs and adults was week 16, whereas week 31 was optimum for a single AA against larvae. However, the optimum combination of 2 AA's in 1 yr was weeks 16 and 27. The explanation for the optimum effect of this combination is that AA16 eliminates a high proportion of adult females that would otherwise produce eggs and larvae during the latter part of the season, and AA27 eliminates most of the larvae produced during the early part of the season by adult females that were not eliminated by AA16. Fig. 1 shows the effects on LST of AA during the year of treatment.

Although these simulations have identified optimum weeks for AA, the effect on populations of LST is not highly sensitive to timing of AA. For example, a range of weeks (14–18) provided 3rd-yr reductions of adults that varied little (29–36%). The effect of combinations of 2 AA's in year 1, ranging from weeks 16–25 to 16–29, also varied little (56–70% 3rd-yr reductions). This flexibility in the timing of AA increases the potential usefulness of this technology in actual programs where precise timing may be difficult to achieve.

Fig. 2A shows the effects of various levels of AA on populations of LST over a 10-yr period. These simulation results suggest that the AA16 and AA27 combination must be applied for 3 consecutive yr (a total of six applications) to reduce and maintain densities of unfed adults below the threshold level during a 10-yr period in eastern Oklahoma. This strategy provided rapid reduction in densities of LST and also was at least as efficient as other AA strategies in maintaining densities below the threshold for a 10-yr period.

Vegetative Management (VM). Fig. 2B shows simulation results with various levels of VM in a 4-yr cycle. These results indicate that VM100 will reduce the density of adult LST below the threshold by year 6 and suggest that VM50 could be used to eventually reduce the density of LST below the threshold level. A strategy that combines these levels (VM100, year 1; VM50, years 2, 5, 9 [not shown]) reduced the adult density below the threshold by year 3 and maintained it below the threshold for the remainder of a 10-yr period. The VM simulations of 25, 50, and 100% of free-living LST populations do not necessarily represent equivalent proportions of the management area because wooded habitat would contain higher densities of LST than meadow habitat. VM technology could be selectively implemented in optimum habitat where densities of LST are higher than the mean density of the total population.

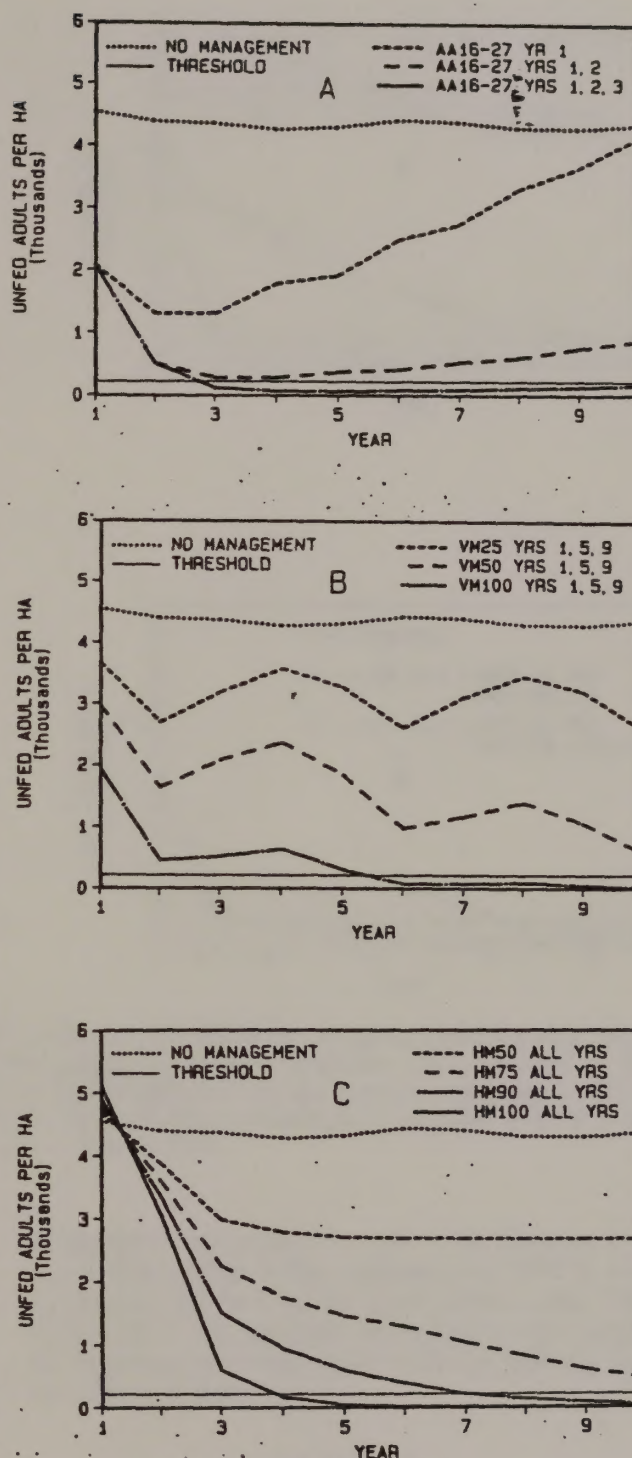


Fig. 2. Simulated trends of LST populations in eastern Oklahoma subjected to management technologies used alone at different levels and frequencies. (A) AA is followed by week and year of treatment; (B) VM is followed by the percentage of population coverage and year of treatment; (C) HM is followed by the percent reduction in WTD population for all years.

Host Management (HM). Fig. 2C presents 10-yr simulation results with all levels of HM. These results reveal the primary disadvantage of using HM alone (i.e., the long period required to reduce the densities of adults below the threshold level). However, results in Fig. 2C indicate that HM100

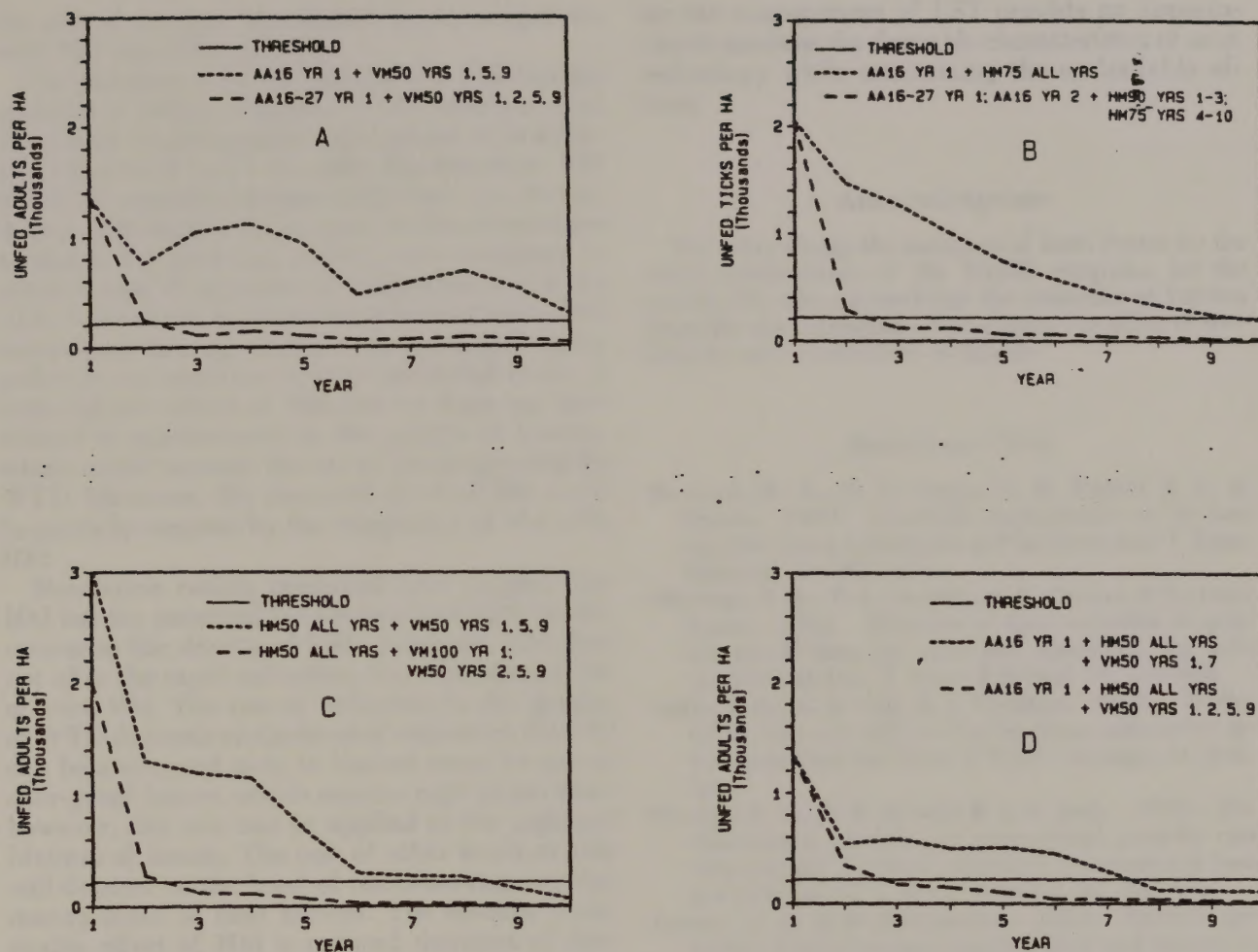


Fig. 3. Simulated trends of LST populations in eastern Oklahoma subjected to integrated management technologies at different levels and frequencies. AA is followed by week and year of treatment; VM is followed by the percentage of population coverage and year of treatment; HM is followed by the percent reduction in WTD population for all years; a comparable mean density of unfed adults from an unmanaged population is $4,372 \pm 82$ SD. (A) AA $\times$ VM; (B) AA $\times$ HM; (C) HM $\times$ VM; (D) AA $\times$ HM $\times$ VM).

and HM90 reduced the density of adult LST below the threshold by years 4 and 7, respectively, and that HM75 would eventually reduce the adult density below the threshold. We emphasize here that our HM model considers only wildlife ecosystems with WTD as the principal host for LST. Obviously, in agricultural areas, other suitable hosts for adults, such as cattle, horses, coyotes, and domestic dogs, will influence the rate of increase of LST.

Integrated Management Strategies. As expected, the results of our computer simulations in Fig. 3 A-D show that each technology can be used at lower levels for satisfactory management of LST when integrated with other technologies than when used alone. In each graph of Fig. 3, one strategy was designed to reduce densities of adult LST below the threshold level as quickly as possible and then maintain densities below the threshold for a 10-yr period with minimum levels of each management technology. Also in each graph, results with an alternate strategy are presented that confirm that lower levels of these technologies produce unsatisfactory results. All of these strategies are

designed to minimize the use of AA because it is more costly than other technologies. HM is also minimized when used in combinations with VM to identify LST management strategies that might allow adequate densities of WTD for hunting and recreational observation.

Discussion

Our simulation results show that AA is faster acting than VM or HM; however, AA is relatively expensive and has potentially undesirable environmental consequences if not applied in accordance with label directions. Granular formulations of acaricides are less likely to cause undesirable effects than liquid formulations because they drift less and do not adhere to vegetation. Current costs for aerial application of granular acaricides are \$20-30/ha. Thus, six AA's over a 10-yr period would equal \$12-18/ha per year. This high cost could be reduced somewhat by selective application of acaricides to portions of the target area infested with higher than average densities of LST. Moreover,

the cost of AA can be reduced by its integration with VM and HM, or both.

Our simulation results indicate that VM has the potential to reduce densities of LST within several years after implementation and seems to be effective when used in a 4-yr cycle. Furthermore, VM should be considerably less costly than AA. Nevertheless, VM requires human and material resources necessary for planning, timing, and execution to achieve near elimination of protective mulch for LST. Potential undesirable side effects of controlled burning are damage to timber resources and smoke pollution on roadways and in inhabited areas. A potential side effect of VM that we have not considered is improvement in the quality of browse, which could increase the use of the target area by WTD. However, this potential effect of VM could be partially negated by the integration of VM with HM.

Simulation results presented here suggest that HM has the potential for producing long-term decreases in the density of LST. However, HM does not offer the rapid reduction characteristics of AA or even VM. The cost of reduction in the density of WTD depends on the level of reduction. HM100 can be attempted only in limited areas by use of deer-proof fences, which require high initial costs; however, this cost can be applied to the expected lifetime of fences. The cost of other levels of HM will depend on the level of resources required for management of deer harvest. The obvious undesirable effect of HM is reduced densities of deer for hunting and recreational observation. The results of our simulations with HM indicate that complete elimination of WTD should not be necessary. Overall, our results suggested that 6.18 deer per 100 ha would not support densities of LST exceeding the arbitrary threshold. However, we emphasize that our HM model has not been fully validated. Furthermore, as previously indicated, LSTSIM does not address the problem of clumped distribution of LST. Thus, densities of LST in optimum habitat could be above, while the overall density is below, the threshold level for LST.

Our computer simulations suggest that integrated strategies with conventional technologies could be considered for area-wide management of populations of LST in recreational and other target areas where WTD are the principal hosts. Although our simulations are only for eastern Oklahoma, we think that our management models could also provide useful results for other locations because the LSTSIM model of population dynamics is applicable over the entire geographic range of LST in the United States. The actual use of strategies simulated in this study will be determined by factors such as the economic and medical importance of LST in a target area; available resources to plan, finance, implement, and evaluate a management program; and the potential detriments and benefits of LST management to private landowners or the affected public. We think that integrated strategies

for the management of LST provide an opportunity to combine the desirable characteristics of each technology while minimizing the undesirable effects.

Acknowledgment

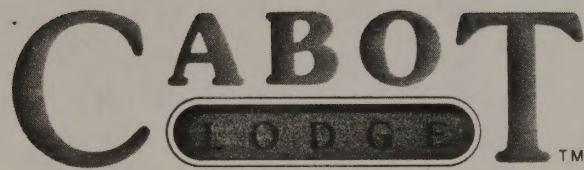
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Cabot Lodge
Locations:

October 15, 1987

Tallahassee, FL
Hattiesburg, MS
Ridgeland, MS
Nashville, TN

Ms. Pat Martin
USDA - ARS
P.O. Box 14565
Gainesville, FL 32604

Dear Ms. Martin;

Thank you for choosing the Gainesville Cabot Lodge for your
rooming accomodation needs.

Below are your confirmation numbers for the names given to me
today, 10/15/87:

	G.D. Thomas	05649GTH	
	C.D. Gilbertson	05650GGI	
	Ralph Bram	05651GBR	
7:00	{F.S. Guillot}		
	{J.A. Miller}	05654GGU	
	Dr. Miller	05655GMI	
	Dr. Shade	05657GSH	
	Jim Whitten	05658GWH	- 3 nights

Please do not hesitate to contact me if you have any questions,
(904) 375-2400, ext. 296.

We look forward to serving you.

Sincerely,

Cleita Rappleyea
Cleita Rappleyea
Director of Sales

Haile - Home
375-0428

Posted: Mon Aug 24, 1987 7:36 AM CDT

Msg: GGIH-2465-5515

From: DIR.IAMARL

To: rbram, lc.kerrville, lc.lincoln, rl.lil, lc.fargo

CC: dir.iamarl

Subj: See Below

August 21, 1987

SUBJECT: 1987 Workshop for the ARS Modelling and Simulation
Network for Filth Flies Affecting Livestock and Poultry

TO:	R. A. Bram	G. A. Mount
	L. M. Cooksey	D. A. Focks
	J. A. Hogsette	R. S. Patterson
	J. A. Miller	F. S. Guillot
	S. E. Kunz	C. B. Gilbertson
	G. D. Thomas	R. W. Miller
	L. G. Pickens	C. J. Whitten
	D. K. Hayes	J. E. George

FROM: D. G. Haile
Agricultural Engineer

This letter provides an agenda (attached) and other information concerning the subject workshop. The workshop will be held October 21-22, 1987 in Gainesville, Florida, in accordance with discussions during the original organizational meeting of the subject network and an informal meeting in Reno. A block of rooms has been reserved at the Cabot Lodge (3726 SW 40th Blvd., Gainesville) for those from other locations. Please contact Ms. Pat Martin at FTS 947-7941 or commercial 904-374-5941 to let us know your travel plans and we will confirm the reservations.

The purpose of the workshop will be to review progress toward development of PC based models for each fly species (Phase I), reevaluate our approach and objectives, and to develop plans and a timetable for accomplishment of the next phase. The attached agenda allows 45 minutes for each group to present the status of their model. An IBM-PC compatible computer with an RGB projector will be available for demonstrations of software. All software should be brought on 5-1/4 inch floppy disks. Presentations of other models under development at Gainesville will also be made. The final morning of the meeting will be reserved for development of future plans.

If there are questions concerning the meeting, facilities or equipment please contact me (FTS 947-7928 or commercial 904-374-5928). I am looking forward to seeing everyone in Gainesville and to an interesting and productive workshop.

*Cabot Lodge
800 843 8735
904 375 2400*

AGENDA

1987 WORKSHOP FOR THE ARS MODELLING AND SIMULATION
NETWORK FOR FILTH FLIES AFFECTING LIVESTOCK AND POULTRY

October 21-22, 1987

Gainesville, Florida

Wednesday, Oct. 21

8:15 - Introduction and Review D. G. Haile

Presentation of Specific Fly Models and Software Demonstrations:

8:30 - Horn Fly J. A. Miller

9:15 - Face Fly R. W. Miller

10:00 - Coffee Break

10:15 - House Fly D. G. Haile

11:00 - Stable Fly C. B. Gilbertson

11:45 - Lunch

Presentation of Other Models Under Development by the Computer
Modelling Unit, ARS, Gainesville:

1:00 - Boophilus Cattle Tick / Babesia L. M. Cooksey

1:45 - Rice Field Mosquitoes D. A. Focks

2:30 - Coffee Break

2:45 - American Dog Tick G. A. Mount

3:30 - Tour of equipment and facilities of the Gainesville
Modelling Unit

4:30 - Adjourn day one

Thursday, Oct. 22

8:15 - 11:30 Open Planning Session - Topics will include:

1. Network objectives and approach, including decisions regarding software, hardware and model structure.
2. Priority data needs for model refinement and verification - Identify responsible scientist or group and timetable.
3. Programming and software needs - Identify responsible scientist or group and timetable.
4. Integration of models and needs for increased network interaction and cooperation.
5. Expansion of models and software to simulate full livestock or poultry production systems.
6. Integration of expert systems and simulation models.
7. Involvement of other individuals, groups or agencies.
8. Overall project timetable and plans for the next network meeting.

11:30 - Concluding Remarks D. G. Haile

11:45 - Adjourn meeting

